Electrical Engineering – Electronic Systems

Midterm Exam Electronic-Systems Engineering – 5XIC0 – 7 December 2023

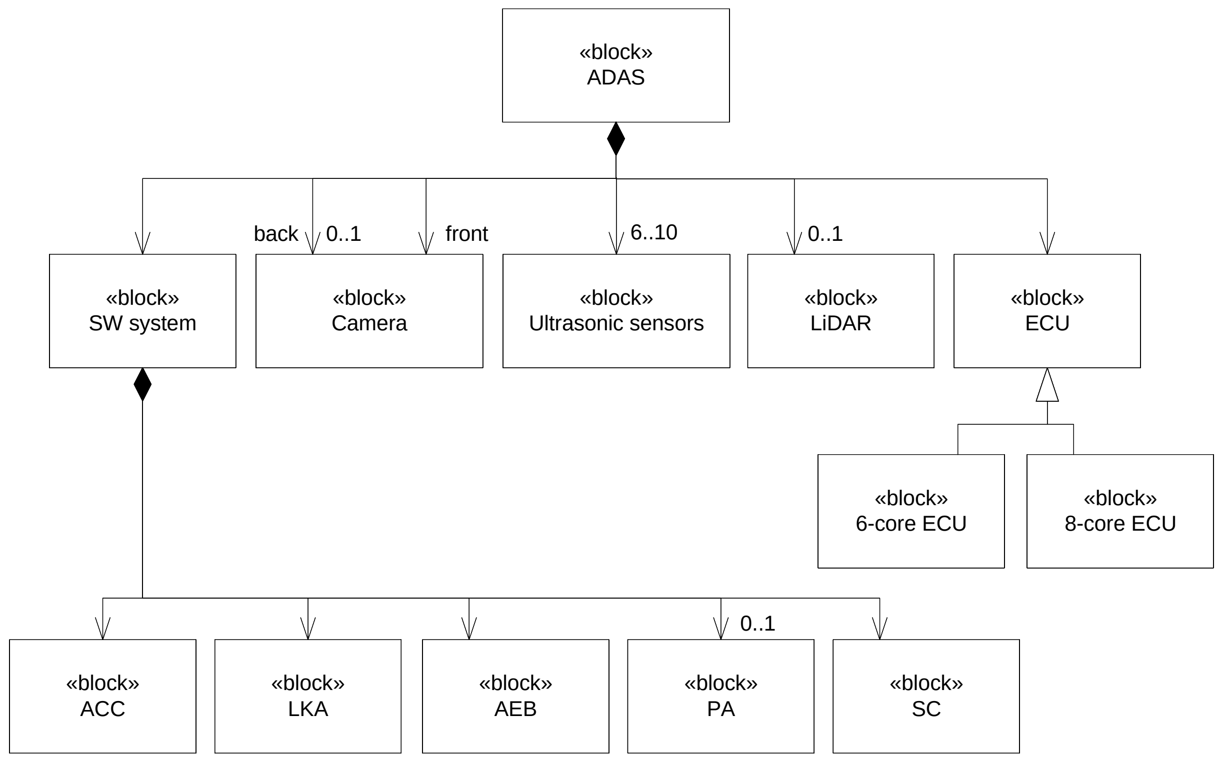
last name: ____________________ initials: ________ student id: ____________

An Advanced Driver-Assistance System (ADAS)

Throughout this exam, we consider an ADAS for cars. The ADAS provides a number of functionalities: Adaptive Cruise Control (ACC), Lane-Keeping Assist (LKA), Automatic Emergency Braking (AEB), and, optionally, Park Assist (PA). A software subsystem implements these functionalities as separate, independent software (SW) components. A Supervisory Controller (SC) is a software component in the SW subsystem that controls the ADAS functionalities. The ADAS contains a single multicore Electronic Control Unit (ECU) that runs the SW. The ADAS has one or two cameras (front, back), six to ten ultrasonic sensors, and optionally one LiDAR sensor to sense the environment. These sensors send their data directly to the ECU, where it is processed by the respective functionalities. The ADAS continuously receives the speed of the car as input. It may control the engine throttle, the steering wheel, and the brakes (which are themselves not part of the ADAS). These actuation commands are sent by the SC. The system may come in different configurations. The back camera is only included if PA is provided. All functionalities use the front camera and the ultrasonic sensors, which are therefore always included. ACC and AEB additionally use LiDAR if available. If a LiDAR sensor is present and PA is provided, then the ECU is an 8-core ECU; otherwise, a 6-core ECU is used.

(15 points) Question 1 – Block Definition Diagram

Provide a block definition diagram for the ADAS. There is no need to differentiate individual ultrasonic sensors.



(5 points) Question 2 – Configurations

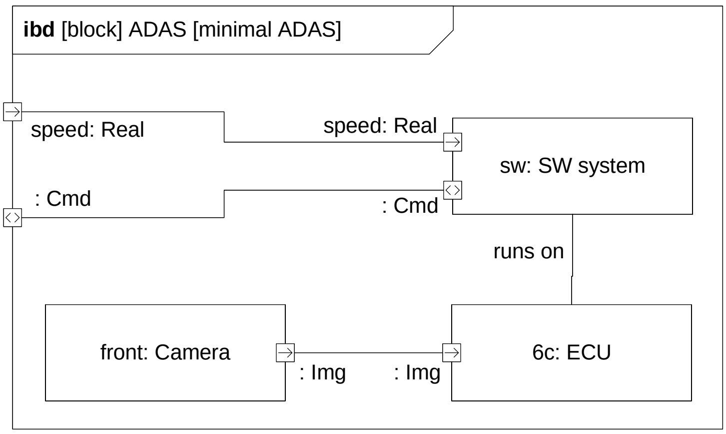
How many parts does an ADAS have in its minimal configuration? And how many parts does it maximally have? How many different configurations are possible? Consider only options with an even number of ultrasonic sensors. Consider SW components as parts. Motivate your answer.

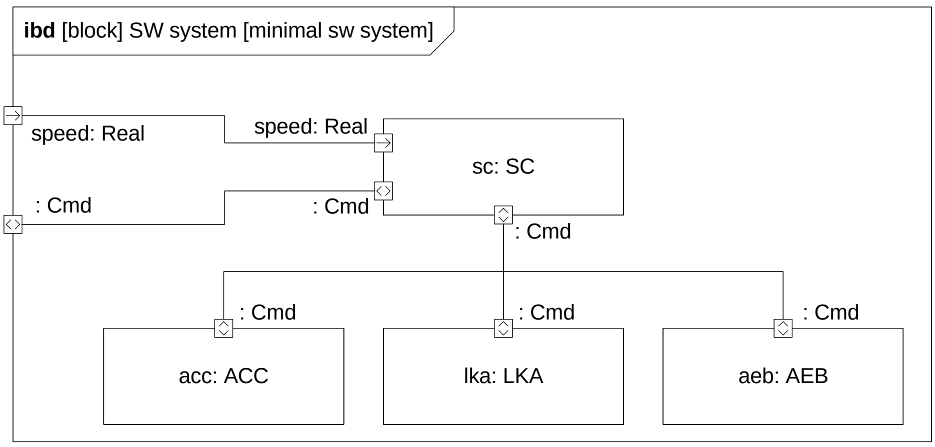
The LiDAR, the PA, and the back camera are optional. At least 6 ultrasonic sensors are included. Counting the SW subsystem as a separate part yields 13 parts in total (5 SW components, 7 sensors, and 1 ECU). In its maximal configuration, 7 components are added (LiDAR, PA, back camera, 4 ultrasonic sensors), yielding a total of 20 parts. (If the SW subsystem is not counted as a separate part, then the numbers are 12 and 19, respectively.)

The system comes in twelve different configurations: with/without LiDAR, with/without PA and back camera, with 6, 8 or 10 ultrasonic sensors. This gives $2 \times 2 \times 3 = 12$ configurations.

(10 points) Question 3 – Internal Block Diagrams

Provide internal block diagrams for both the SW system block and the ADAS block in the minimal configuration of the ADAS. Make the command flow between SC and the other SW components explicit. Make also the data flow from the sensors to the ECU explicit, as well as the flow of actuation commands. You may omit the ultrasonic sensors from your diagrams.





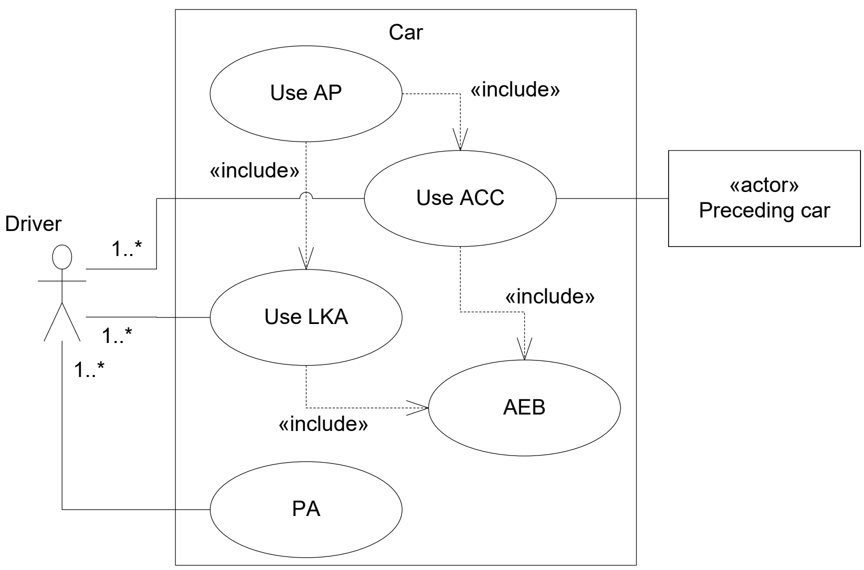
last name: ____________________ initials: ________ student id: ____________

Driving the Car

The primary user of the car is the driver. The driver is responsible for activating and deactivating ACC, LKA, and PA. AEB is always active during normal driving; it is deactivated during PA. When active, ACC continuously monitors speed and the distance to a potential car in front. Based on this information, it computes a new speed target and sends this target via a command to the SC. If the distance to a car in front drops for some reason below a predefined, speed-dependent threshold, then the SC activates AEB, overruling ACC. LKA, when active, continuously monitors the road. It extracts relevant features from the received images, after which it computes and outputs the desired steering angle via a cmd to the SC. The SC ultimately sends the appropriate commands to control throttle, steering angle, and braking instructions to the relevant engine, steering, and braking controllers. ACC and LKA can run independently, but also simultaneously, referred to as the Auto Pilot (AP) use case.

(10 points) Question 4 – A Use-Case Diagram

Provide a use-case diagram capturing the described use cases for the ADAS, identifying relevant actors and included use cases.



(A diagram with a 'normal driving' use case that includes the AP/ACC/LKA use cases is also possible.)

Continue on Next Page

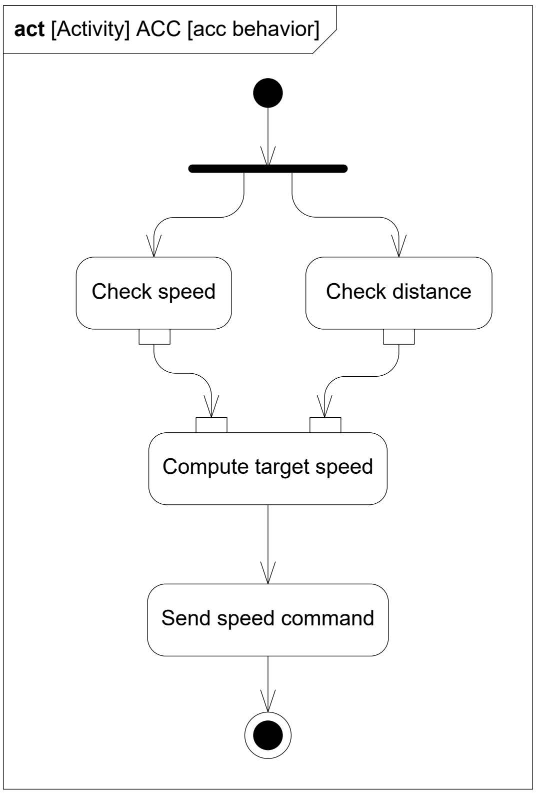
(10 points) Question 5 – A Use-Case Description

Provide a use-case description for the AP use case. Include both the normal AP operation and the exceptional scenario when AEB needs to be activated.

name:	AP
primary actor:	Driver
supporting actors:	Preceding Car
preconditions:	ACC and LKA are activated by the driver
postconditions:	The car is kept within the recognized lane, with a safe distance to the preceding car (if present)
main scenario:	AP runs in a continuous loop, running ACC and LKA in parallel - ACC checks speed - ACC checks distance - ACC computes speed target - ACC sends speed target command - LKA receives an image - LKA extracts features - LKA computes steering angle - LKA outputs steering angle cmd - SC decides on steering angle and speed target - SC sends steering and throttle commands
alternative scenarios:	The distance to the preceding car drops below the predefined AEB threshold. The SC sends a braking command.

Activity Diagrams

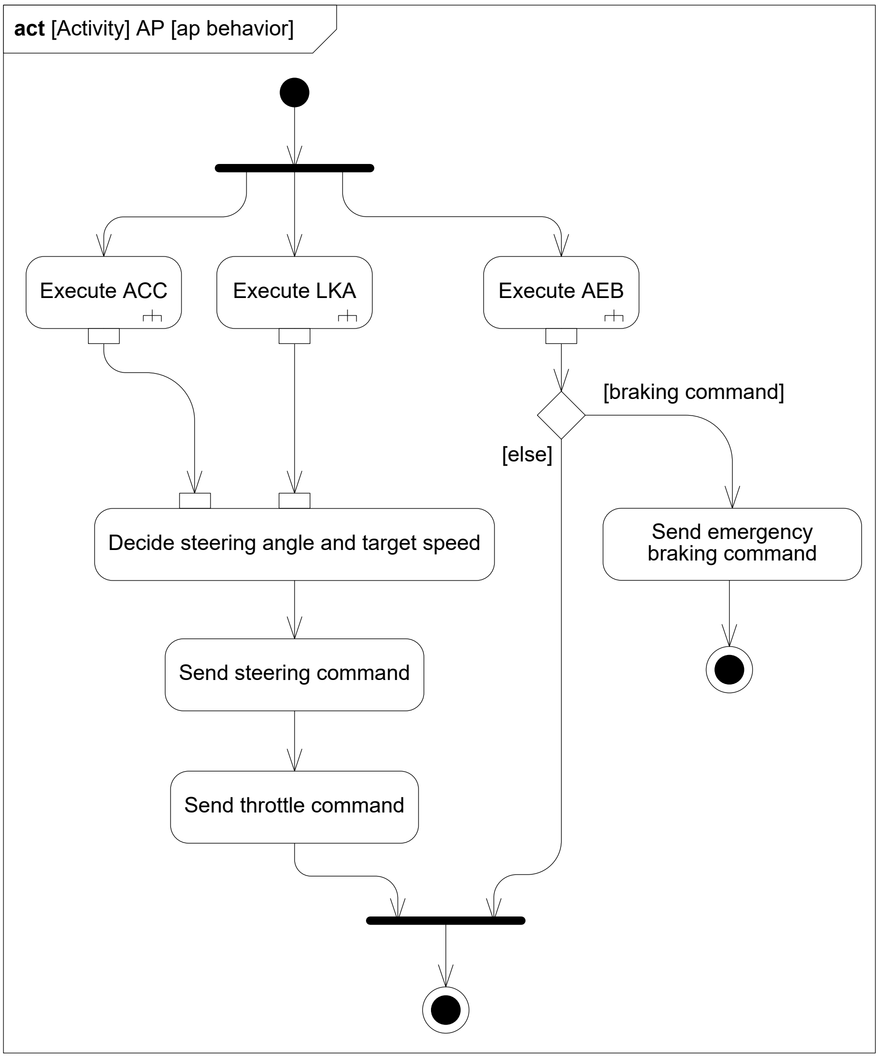
The following activity diagram specifies the behavior for one loop iteration of the ACC SW component. It refines the ACC use case.



last name: ______________________ initials: _________ student id: ______________

(10 points) Question 6 – An Activity Diagram

Assume that, in line with activity ACC, activities LKA and AEB have been defined. Consider the AP activity that is defined to refine the AP use case. Provide an activity diagram for one loop iteration of the AP activity. The activity diagram should consider both the normal AP behavior and the exceptional emergency braking scenario.

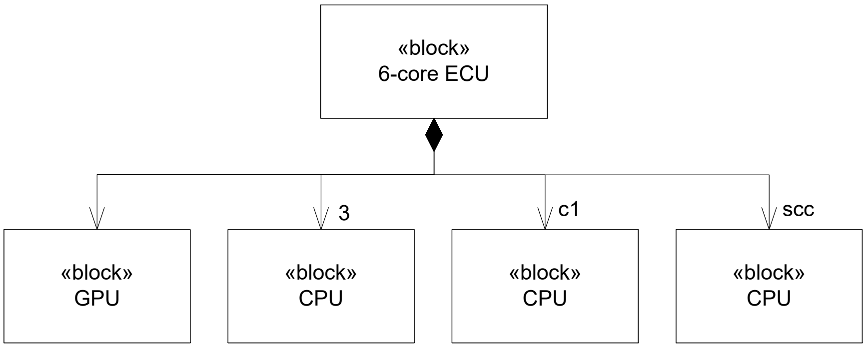


Note that an emergency braking command terminates the loop (which is why the full activity is terminated after receiving a breaking command from the AEB activity).

Continue on Next Page

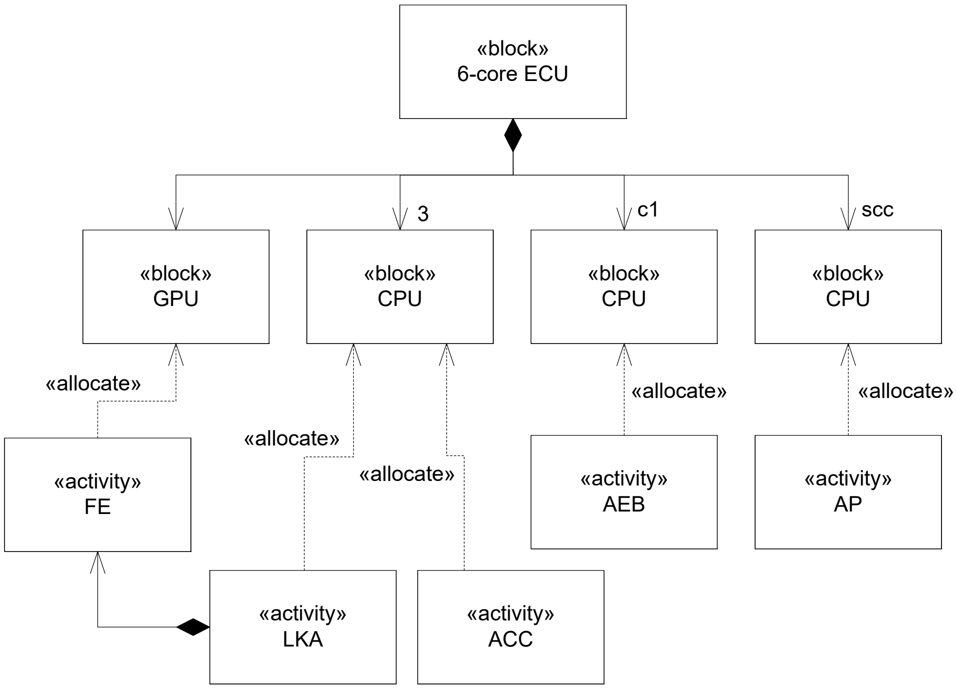
(10 points) Question 7 – Allocation

Consider the following block definition diagram for the 6-core ECU.



The ECU has 1 CPU core (scc) that executes the SC. The GPU core is used for feature extraction when LKA is active. Core c1 is reserved for AEB. The other three cores can be used freely for executing the ADAS SW. Provide an allocation of the AP activity of the previous question to the parts of the 6-core ECU. The allocation should include activities that AP calls. (Hint: What type of allocation are you providing? What about the feature extraction functionality of LKA?)

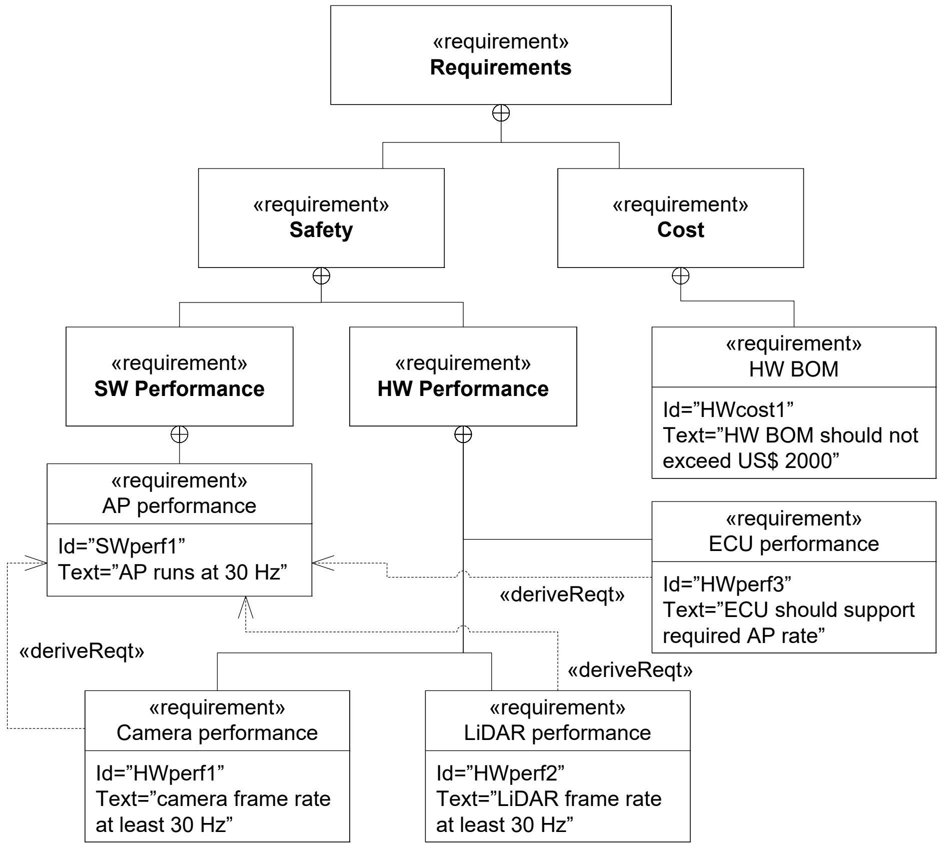
The following is a functional allocation of definition. It allocates activities to blocks. The feature extraction functionality of the LKA activity is encapsulated in a subactivity FE that is allocated to the GPU.



last name: ____________________ initials: ________ student id: ____________

(10 points) Question 8 – Requirements

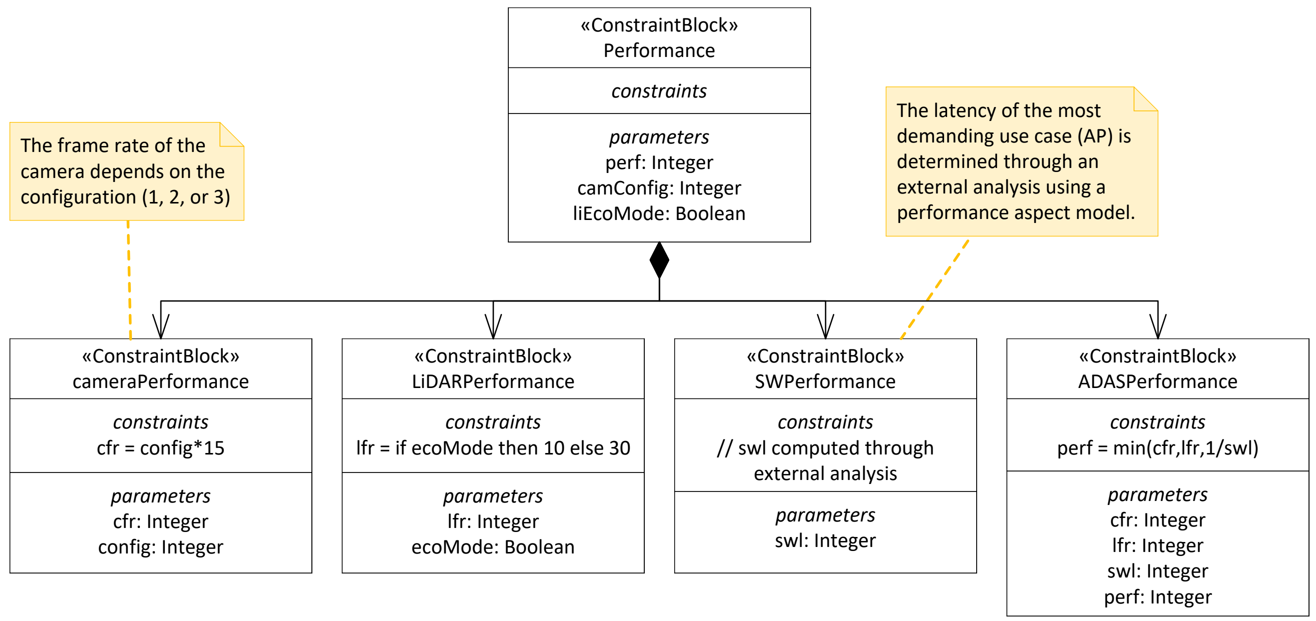
A primary requirement for the car is that it is safe to drive. The ADAS-related safety requirements contain among others performance requirements on the SW and on the HW. The most demanding use case for the SW system is AP. It should run at a 30 Hz rate. As a consequence, also the (front) camera and the LiDAR should support that rate. Clearly, also the ECU should support the desired rate. The total BOM for the HW should not exceed US$ 2000 though. Provide a requirements diagram that captures the described requirements, their breakdown, and their relationships.



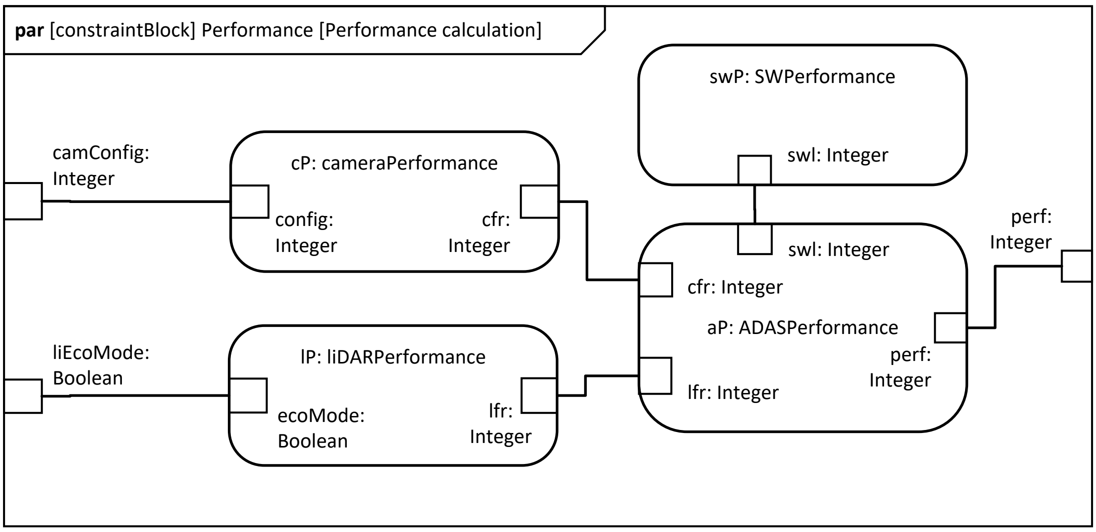
Continue on Next Page

(10 points) Question 9 – Performance analysis

Consider the following block definition diagram for the ADAS Performance measure of effectiveness.



Provide a parametric diagram that captures the parameter bindings for the Performance measure.



(10 points) Question 10 – Trade offs

The HW department has selected three candidate boards for the 8-core ECU. One board of US$ 750, one of US$ 600, and one of US$ 500. The first one will be used for the initial version of the car, that starts selling in July 2024. Marketing informs you that the expected sales volume for the performance edition of the car that comes with the 8-core ECU is 24.000, 2.000 cars per month. For July 2025, a new version of the car is planned, after a considerable redesign. Given that the car currently under development will be on the market for one year, management wants to know whether or not it is worth investing in an intermediate update of the performance version of the car. Finances informs you that the extra NRE for implementing the SW on the US$ 600 and US$ 500 boards while still meeting the requirements is expected to be US$ 3.25M resp. US$ 4.25M, based on effort estimates of the SW department and a development time of 2 resp. 3 months. Which option should be chosen: no intermediate update, an update to the US$ 600 board or an update to the US$ 500 board? Motivate your answer.

Assume the no-update scenario as the reference. An update to the US$ 600 board after 2 months will lead to an extra NRE costs of US$ 3.25M. It will lead to a BOM saving of 10 months $\times$ 2000 cars $\times$ US$ 150 = US$ 3M. So this is not an interesting option.

An update to the US$ 500 board after 3 months will lead to an extra NRE costs of US$ 4.25M. It will lead to a BOM saving of 9 months $\times$ 2000 cars $\times$ US$ 250 = US$ 4.5M. Since the savings exceed the extra costs, this option should be pursued.

Final Page